Testimony to U. S. House Committee on Agriculture

RURAL BROADBAND - EXAMINING INTERNET CONNECTIVITY NEEDS AND OPPORTUNITIES IN RURAL AMERICA

Johnny Park, Ph.D.
CEO, Wabash Heartland Innovation Network (WHIN)
April 20, 2021

I would like to thank Chairman Scott, Ranking Member Thompson and the Committee for the opportunity to speak with you today.

This invitation came about after a recent conversation we had with Congressman Baird to catch him up on WHIN activities. He found out that we recently had a successful test flight for the aerostat we are deploying to serve rural broadband needs in our ten-county region of North Central Indiana. Ours is the first aerostat, by the way, to be deployed long term for commercial rural broadband in the U.S.

As we explained why we had included an aerostat in our network, Congressman Baird was struck by how valuable such innovative alternative technologies could be to helping solve the digital divide. We greatly appreciate his introduction on our behalf to Ranking Member Thompson.

1.0 Revisiting the Rural Broadband Problem To Make Room for Innovations Like The Aerostat

The aerostat is indeed a fascinating and potentially game-changing contribution to solving rural broadband and we are happy to tell you all about it. It is, however, but one innovation among many that will be needed to solve the digital divide.

And innovation for rural broadband is in full swing. It is high on university research agendas. U.S. Ignite and the NSF are due to announce who will build out the next Platform for Advanced Wireless Research (PAWR), this one dedicated to rural broadband. The FCC has made CBRS and TV White space available, both high bandwidth spectrum eminently suited to rural applications. Industry, from Big Tech to gear companies to Elon Musk, are developing new products accordingly.

And so is funding pouring out. Just about every major funding bill that has been signed into law in the past several years has included substantial dollars for rural broadband.

But the digital divide remains: we can't get over the hump. The finish line is ever out of reach. So far, the innovation value chain that leads to solutions, even with help of major federal investment, is not delivering, or at least not delivering fast enough.

We also sensed from reading the report for the last Farm Bill a certain frustration on the part of Members with how to reconcile huge federal investments with infrastructure that can become obsolete even before it is built. There is a quite natural longing for solutions, if and when they come, to be "future proof" and to be "built right the first time."

Somehow, the enormous effort to solve rural broadband doesn't seem to be satisfying anyone, and that is certainly true in the very rural ten-county WHIN region of North Central Indiana.

In part, this could be a problem of unrealistic expectations that arise out of unchallenged assumptions and conventional wisdom. For example, that word "infrastructure" can lead to the misperception that telecommunications infrastructure should have the same kind of long and stable future as physical roads and bridges.

There are indeed solidly physical aspects to telecommunications infrastructure, but unfortunately they are nothing like roads and bridges. Even the lowest, most physical layer in a network, like the glass of fiber, has intelligence built into it, such as the ability to transmit multiple wavelengths. This allows a physical medium to interface with the higher layers in a transmission whose functions are even more abstract, such as data, addresses, protocols, logic and so forth. In other words, there is no "dumb," neutral, physical-only, part of a network, including fiber, that carries data inertly the way a concrete road carries cars.

That is one reason that fiber is so expensive. And while it has a relatively long useful life, at least in the telecommunications world, fiber is fabricated to allow certain bandwidth limits that meet current standards. Standards have a purpose and value in extending useful life. But they can also limit innovation and make it harder to meet a growing need. Eventually, something has to give because the spectrum on which telecommunications depends is a fixed, limited resource. The only way to get more of it is to innovate technology to get more performance out of what is already there. This means standards have to change and replacement of infrastructure must follow.

And by the way, the future of roads is that way, too. They are becoming smart as they are equipped with sensors. All infrastructure is going to look more and more like telecommunications infrastructure as the Internet of Things (IoT) barrels toward us from the future.

Another expectation that deserves a hard look is the one around fiber being not only stable, but the key to solving the rural broadband problem. Wherever it is deployed, fiber is utterly necessary to broadband, but it is not sufficient to accomplish broadband service. This is because fiber rarely, if ever, delivers service directly to user equipment (UE). All mobile and most non-mobile network use requires some amount of wireless transmission, and however much fiber we lay, what the user experiences in service is only as good as the weakest link in the network. That link is wireless technology, which is historically weaker than fiber. Wireless technology is indeed a complex partner to fiber, embodying strength, weakness, opportunity and threat.

Finally, there is the related and subtle expectation that what works for dense urban areas just needs to be stretched out to fit less dense, rural areas. In this view, rural areas are vast swaths of digital deserts: a lot of digitally-irrelevant empty space between users, as if a city had been attached to a rubber mat and stretched out over the countryside.

The danger is that seeing rural America that way leads to implementing rural broadband that way. For one thing, rural terrain is not homogeneous, and it can be very unfriendly to terrestrial solutions of all sorts.

Rural areas are also digitally diverse. There are small communities that are oases of density. Dense use can develop spontaneously when a festival pops up and tourists arrive, or at a Friday night football game when most of the population that is normally spread out across a county finds itself packed into an acre or two, with cell phones ablazing. Rural residents tend to do a lot of driving and rely on mobile phones en route.

Then there is the fact that rural areas are no longer digital deserts at all, because those seemingly empty farm fields are increasingly populated by sensors that need wireless service. Sensors that serve digital agriculture are typically low power and operated by batteries that must last for years. This means that traditional broadband won't work because it draws too much power and that is okay: sensors don't need broadband for their uplink. Their transmissions do, however, need backhaul. So IoT needs something different to complement broadband, and that service is going to be just as important to rural development as broadband.

Rural broadband is also not starting from scratch. Recent investment has resulted in very useful and important deployment of fiber. That it hasn't always closed the gap to the user doesn't mean it was a poor investment. And some fixed wireless providers are upgrading to newly available spectrum like CBRS. They are also taking advantage of grain legs and other built structures typically found in rural areas to avoid building expensive towers.

But in the WHIN region alone, there are 30 service providers, with widely varying levels of service, a multitude of technologies, and inconsistent plans to upgrade. A huge challenge to consistent rural broadband service is to incentivize the marketplace to provide the consistent, high-quality service the region needs.

The bottom line is that rural connectivity needs are not always what they seem to be: they are complex, dynamic and don't lend themselves to one-size-fits-all solutions. Rural telecommunications will have to be solved creatively and strategically, with a variety of flexible and dynamic solutions that take into account not only the distances in rural areas, but also environmental and terrain conditions, the jumble of existing technologies, the variety and unpredictability of connectivity usage patterns, and the need for different kinds of spectrum for different problems.

Among other things, this puts a lot of pressure on wireless technology to fill gaps and go where fiber can't without compromising service. Accordingly, as noted above, wireless technology has been enjoying a lot of attention. Notably, at the physical level at least, wireless technology is a less problematic target of investment because it is also less expensive to fabricate, deploy and redeploy than fiber.

There is still plenty of room for even more innovation as the new spectrum, which is very different from conventional broadband spectrum, becomes operational. Wireless transmission is still affected for better and worse by physical issues like positioning, and in some bands, it is always going to be hampered by obstacles.

And there is an opportunity to innovate fiber with different models of deployment.

So what does this complex, vibrant view of rural broadband mean for this Committee and others who are trying to find traction to justify major investments in broadband infrastructure?

First, the notion of rural broadband infrastructure must expand to include not only fiber but also whatever it takes to deliver performance and solutions to users, including fiber.

For example, a percentage of fiber investment could be set aside to support innovation of wireless technology for rural applications including IoT; strategic and integrated use of fiber in conjunction with wireless technologies to achieve optimal performance; middle and last mile solutions that are sustainable; and, attention to ensure that rural connectivity solutions are designed to solve complex problems like elearning, remote work, and telehealth beyond just providing a lot of bandwidth.

We were very impressed to see the note in the House Farm Bill report that an Innovative Broadband Advancement Program had replaced the former Rural Gigabit Program, and to learn that it was signed into law. Even though the provision was not funded, it hit the high points of practical and cost-effective innovation, demonstration, methods of deployment in addition to technology, and flexibility. We commend the Committee for that vision.

We realize that encouraging innovation in a complex technology like broadband, and in a complex service area like rural America, poses a different and difficult set of challenges to funding than are usually faced in infrastructure-related legislation. How, among all of the choices that are emerging, is an investor, including government, to know whether a solution works as intended? Whether it is necessary? Whether it solves the problems users care about? How much value will it return? Is there a sustainable business model? What are its unintended consequences? What will come closest, fastest, to solving the digital divide?

How, in short, can we get innovation funded? And what makes an innovation in rural broadband a good investment? How is that determined? And by whom?

WHIN's aerostat is an example of wireless innovation that can benefit rural broadband. It is being deployed with private grants funds and no public investment. That approach works because WHIN is itself an innovation: a community-based nonprofit with a regional development mission built primarily around scientific and educational purposes.

Though aerostat technology is the reason we are testifying, it is but one example of innovative technologies that can accelerate rural broadband. WHIN is technology-agnostic. The model it has developed organizes innovation around cost effective, efficient, sustainable, rapid results and it has demonstrated the ability to accelerate digitalization, including both Internet of Things (IoT) and its enabling technology, broadband, in the vital rural economic sectors of agriculture and manufacturing.

Private funding is flexible enough to fuel the development of such an innovative model and to demonstrate its value. But what WHIN is doing has useful lessons for others who are trying to solve the problem, including the federal government. For example, WHIN's model addresses "future-proofing" to some degree. It is a project worth continuing with public help, strengthening and scaling up the bold experiment that WHIN's private grant dollars have enabled. That is how public-private partnerships should work, aligning investment with the stages of a project's life-cycle that best fit what a funder is able to do within its purpose.

We begin with a brief description of WHIN. Then we describe the aerostat as an example of how WHIN's unique Living Lab model is demonstrating innovation. We then conclude with a fuller explication of the model and its power to generally organize innovation around results.

2.0 About WHIN

WHIN is the Wabash Heartland Innovation Network. With very generous initial funding from Lilly Endowment Inc., our task is to build a regional ecosystem that can help our rural region attract globally competitive businesses to plant and grow in the Wabash Heartland.

The WHIN region consists of Benton, Carroll, Cass, Clinton, Fountain, Montgomery, Pulaski, Tippecanoe, Warren and White counties in North Central Indiana. Its area is 4,321 sq mi and includes a 90-mile stretch of the Wabash River. The region's population is 391,476 (2019E).

The region's average BEA Per Capita Income in 2019 was $42,276, about 75% of the national average. About 85% of the region's land area is farmland, primarily in corn and beans.

The economic and population center of the WHIN region is in Tippecanoe County, and especially in Greater Lafayette, home of Purdue University in West Lafayette and a regional campus of Ivy Tech Community College in Lafayette. Greater Lafayette hosts vibrant manufacturing including Subaru's North American production plant; Wabash National, North America's largest producer of semi trailers and liquid transportation systems; a metals cluster including Arconic, Nanshan America, Oscar Winski, and ProAxis; a Caterpillar large engine plant; Evonik pharmaceuticals, and an aviation cluster including GE Aviation and Rolls-Royce, with SAAB on the way. About half of the region's population resides in Tippecanoe County.

WHIN is not an ISP, and broadband, rural or otherwise, is not our primary business. And though, as a regional development organization WHIN has a very close working relationship with Purdue University and Ivy Tech Community College, it is a community-based 501c3 whose own purposes are scientific and educational, as well as charitable.

The WHIN innovation in regional development is that it not only has the 501c3 purposes of science and education that are unusual in a community organization, those purposes structure its strategic framework. WHIN does serve the charitable purpose of supporting the quality of life projects and workforce development that are usually expected from organizations like ours. But the organization mainly has the not-so-modest and very specific grant obligation of making our region a globally-recognized center of IoT, the Internet of Things. WHIN is developing its region as a Living Laboratory for all of the technology related to IoT.

Aerostat technology serves the I in IoT, which is to say the internet. As a means of accessing the internet, it is a prospective technology for rural broadband.

3.0 WHIN's Aerostat: A Case Study In Using WHIN's Living Lab To Address Rural Broadband

3.1 How WHIN chose aerostat technology for its Living Lab

WHIN identifies innovative IoT technology, puts it to real use in its regional Living Lab, and generates research and educational support from that use. The process begins with an extensive vetting process that examines both the prospective technology and the prospective tech partner that produces it.

WHIN looks for promising technology that is commercial or near-commercial, has a sustainable business model, can be deployed rapidly, will have immediate impact, and that can offer interesting test cases to move IoT adoption forward.

WHIN began its association with RTO Wireless through connections both have in Silicon Valley. The company is headquartered in Massachusetts with a research office in California. It offers fixed wireless service on the east coast, but its principals are very interested in wireless innovation, specifically for rural broadband. RTO is a Microsoft Airband partner. It has strong connections with the military. When WHIN met RTO, it had begun a new venture to adapt military aerostat technology that has a long and successful record serving telecommunication needs on battlefields, for use in domestic applications, including rural broadband.

The company was far enough along in the adaptation to be nearing a contract with AT&T to utilize an RTO aerostat for FirstNet services. FirstNet is the government-funded program developed after 9/11 to ensure that first responders can communicate when commercial communications are down because of a national emergency or natural disaster. AT&T has the contract and it, in turn, contracted with RTO to do the work necessary to prepare an aerostat for flight, including its payload of radios and antennas, as well as to provide flight operations support until AT&T's crew could be trained.

Over time, that contract was executed and an RTO aerostat successfully tested at the famous Tuskegee Air Force base in Alabama. This test was conducted twice and closely tracked by the FirstNet program and the FAA. AT&T and RTO demonstrated that the aerostat could be operated safely, and earned the FAA's support for these emergency deployments. During Hurricane Laura in Louisiana, AT&T and RTO deployed the RTO aerostat and provided communications to emergency personnel.

RTO previously conducted successful flight and telecom tests in Baltic, North Dakota, demonstrating a propagation map that far exceeded the reach of terrestrial towers in the WHIN region.

Based on that information, WHIN recognized the disruptive potential of the aerostat and decided to deploy an RTO Wireless AeroSite™ in its Living Lab, making it the first long-term deployment of the technology in the U.S. for commercial rural broadband.

3.2 Aerostat technology and the RTO Wireless AeroSite™ in particular

3.2.1 History and use

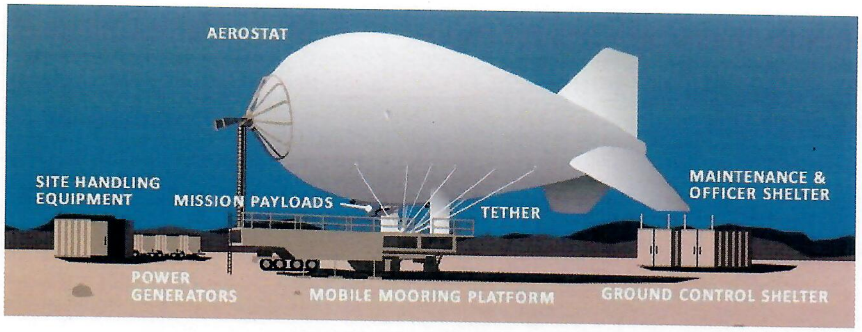
Aerostats have been in service since the early 1900s. Since 1978 the United States has maintained eleven tethered aerostats sites along its southern borders on a 24/7/365 basis, operating as high as 18,000 feet and carrying radar units for drug interdiction purposes, persistent surveillance and other applications. Aerostats have also been used for decades by the military for communications on battlefields.

The demonstrated use of aerostats in these situations suggests that they would be an ideal technology for rural broadband because rural terrain, user density, and user mobility have much in common with military service areas.

Beyond communications, aerostats could be an IoT solution for rural needs including forestry management (hyperspectral), fire and hot spot detection (thermal), imaging for precision agriculture, environmental monitoring, and livestock tracking and monitoring.

Aerostats can be used for emergency and law enforcement situations, like the FirstNet service mentioned above. WHIN envisions the potential for aerostats to serve as an immediate solution for deploying rural broadband connectivity, as telehealth and remote learning needs are immediate. In the event that fiber or other networks overbuild the aerostat coverage area over time, then the permanent aerostats can be switched to emergency networks that get deployed during massive natural disasters or acts of terrorism or war.

3.2.2. Equipment



The aerostat is a tethered balloon, filled in its center with helium for lift and compartments of air in the nose and tail that can be used to adjust its flight in various weather conditions. The aerostat's aerodynamic design helps stabilize it in flight.

The aerostat is deployed in a fenced, secure, graveled compound located and sized to allow for a 45 degree cone of operational space around the tether that ensures the aerostat easily clears other vertical structures during launch and landing.

The full AeroSite™ system includes a mooring trailer that is custom designed to anchor the aerostat in flight, allow it to be launched and landed safely, and connect it with power and fiber.

The mooring trailer also contains avionics to assist flight, launch and landing, as well as remote monitoring.

The trailer remains on wheels and is portable but is anchored to concrete pylons for long term deployment. The compound that serves the aerostat contains a telecom cabinet, generator, equipment storage shed, and the helium truck. The compound needs fiber service and commercial power.

3.2.3. Performance advantages and constraints

The aerostat's tether contains fiber as well as power and its payload consists of radios and antennas. It can therefore provide both access and backhaul.

At an altitude of 500'-2500', depending on model and payload design, the aerostat's altitude offers two significant performance advantages. First, it can position radios and antennas at an optimal altitude to provide line-of-sight communication that exceeds that of typical terrestrial towers, while maintaining low latency that avoids the lag and other problems associated with high latency at higher altitudes. High latency is a problem with satellite technology, for example. Greater line-of-sight benefits rural broadband by enabling signals to reach behind treelines and other obstacles in often-difficult rural terrain.

Second, the aerostat's higher altitude means that its radios and antennas operate in free space, which gives them greater range than they have on the ground. Aerostats generally extract more value from gear.

The main performance constraint is weight: unlike terrestrial towers, the number of radios and antennas an aerostat can carry in its payload is capped. That means that capacity, the number of customers a single aerostat can serve, is also capped, making aerostats unsuitable for high-density areas like cities. But as long as the payload capacity of an aerostat is aligned with the density of its intended service region, which is typically low in rural areas, this constraint is not a disadvantage: a single aerostat can serve a much larger area than a single terrestrial tower. This CapX/OpX efficiency is what gives aerostats their business model advantage.

The other main performance constraint has to do with up time. Aerostats must be brought down monthly for a few hours for service and helium top-off. Though designed to fly in winds up to 80 mph, depending on the model size and actual payload, aerostats may have to be grounded in exceptional weather conditions. Also, as tethered balloons, aerostats fly under Section 101 of FAA regulations, meaning that they are subject to visual flight rules and must stay below the cloud ceiling.

With their low carbon footprint, minimal soil disturbance, and relatively quiet operation aerostats are environmentally friendly. Aerostats would not be typically deployed closer together than 20-25 miles, and at flight altitudes of 500'-2500', they are not visually distracting.

3.2.4. Operational considerations

Though the aerostat itself is unmanned, it requires 24/7 remote monitoring on the ground. Manned operations contribute to the aerostat's OpX, but that is mitigated if aerostats are deployed in a network, allowing a single operator to serve multiple aerostats.

Launch and landing require a team that is well-trained, but only needed occasionally. Though this also contributes to OpX, the team is mustered infrequently. An analogy would be volunteer firemen. In WHIN's case, Purdue University is close by and has an aviation program. It is eager to supply student interns to assist, as they will benefit from a unique opportunity to gain skill in this technology.

Helium is expensive and deflation is to be avoided to keep OpX in line. Normally, only a top off should be required month to month

3.2.5. What is involved in deploying an aerostat

The overarching consideration for deploying an aerostat is that it is regulated by a variety of entities, including local ordinances governing zoning and land use, the FCC controlling telecommunications, and the FAA controlling use of airspace. There are two main differences in the process for aerostats compared to terrestrial towers. First, aerostats are new and the governing mechanisms don't always account for them. Second, the FAA has much more to say about aerostats than it does about terrestrial towers.

For regulatory approvals, it is very important to become familiar not only with requirements but timelines. The permits often depend on each other, and not taking steps in the right order will cost time.

That said, WHIN, which had no experience standing up a commercial network, coordinated with RTO on the site selection and permitting process. RTO brought experience standing up commercial towers but had only deployed aerostats in emergency situations where much permitting is waived. WHIN and RTO used their collective resources to work through the ordinances and processes that agencies required to construct a communications site and a "tethered balloon" deployment. Even with these challenges, WHIN still managed to go from needing to select a site to maiden flight in six months. That time frame is not possible for a terrestrial tower, which can take well over one year to construct and require the ground frost to be thawed.

Specific aerostat ground needs are modest compared to a tower, with no structure construction required. Most of the construction is in grading and finishing the compound and access road, and fencing. The site must have access and easements for power and fiber. An ideal location is a farm field where the compound can be distanced from power lines and vertical structures.

3.3. WHIN's specific configuration

In selecting both site and aerostat model, WHIN's goal was to be able to at least touch the edges of six counties with broadband service and provide LoRaWAN to the entire region with a single aerostat. The intended spectrum is CBRS, with the ability to swap in other spectrum, including very high frequency. The performance goal is 100 Mbps/20 Mbps within a 15-20 mile radius, with capacity to be determined, but sufficient to support a business model

The recommended model was an AeroSite™ 800, which is an 80-foot balloon with a 200 lb payload capacity, and tether for a flight altitude of 1,500 ft.

3.4 WHIN Plan for Operations

As of the end of March, WHIN's aerostat had completed a successful test flight. The LoRaWAN payload is presently being configured, and that will be tested in early June. The next radios to be added to payload will be 5.8 GHz radios that have been used for many years in rural broadband networks. After 5.8 GHz testing is completed, WHIN will replace the 5.8 GHz radios with CBRS radios and begin testing. WHIN will be testing various antennas on all the wireless technologies on the aerostat.

In the meantime, WHIN is contracting with local service providers to provide retail services for the aerostat. WHIN is working with a service provider to provide sufficient backhaul and radio equipment for multiple wireless service providers to be able to utilize the aerostat.

3.5 WHIN's Research Plan

Over the next year, WHIN will test and produce use cases including business plans to determine:

1. The propagation maps that are possible from the aerostat for LoRaWAN, 5.8 GHz and CBRS networks
2. Service capacity for each configuration
3. Use of the aerostat for backhaul
4. The motion of the aerostat and its influence on performance and compliance with any wireless standards, such as CBRS restrictions on movements of certain antennas that are cause by the aerostat
5. How operational considerations impact the business model

WHIN is also deploying terrestrial assets in conjunction with existing commercial terrestrial assets to facilitate testing and provide a variety of real world network configurations and ground-truthing.

WHIN is seeking funding for a second aerostat to both elaborate the business model and to do technical testing with a network of aerostats.

4.0 The WHIN Living Lab Model

WHIN is able to deploy the aerostat in real operations and test its performance thanks to a model it has developed called Living Lab. The model has its roots in a problem WHIN had to solve for itself. In order to meet its grant requirements, it had to find a way to accelerate the adoption of IoT, and, even more specifically the sensor side of IoT, by growers and manufacturers in its ten-county region.

But of course it turned out that IoT is an all or nothing proposition. It can't solve problems unless all of its parts are present: data measurement (sensors), data transmission (broadband), and data analytics/applications (the component that integrates the data into an action plan or solution).

Because commercial sensor technology comes equipped with data analytics, we were left with a two-part problem.

1. Sensor technology is at the stage of development where its next customers, especially in rural markets, don't know yet that they need it, or at least not with the urgency that would lead to rapid adoption.

2. Broadband, on the other hand, is already at urgency and beyond in rural markets. The problem with broadband isn't adoption, it is a combination of affordable availability and slow deployment.

Technology is always in a process of continuous improvement, or the addition of value, by its stakeholders. At different points along this innovation value chain, there are different stakeholders. Early on, it may be a university and the NSF. At another, it is a startup and a VC. At another it is a user with her wallet. Each addition of value involves investment.

We aren't accustomed to thinking of users as adding value, but as noted in the introduction, they have perhaps the most value of all to contribute because only they are the arbiters of whether a technology should stay or go. Of whether it has any value at all.

What WHIN's two IoT problems have in common is that somewhere in their value chains, there is a barrier to real use. For sensor-technology the barriers are related to adoption. For broadband, they are related to being available and accessible. Looked at that way, WHIN's problem was to eliminate barriers.

4.1 Connecting products to real use

Lowering the barriers to adoption is such an important need for WHIN that it has its own part of the Living Lab called WHIN Alliance, consisting of the growers and manufacturers who are willing to adopt if WHIN makes it easy.

A key barrier to easy adoption is the time and effort it takes to identify and assess not only a technology but the company itself. As we saw with the aerostat, WHIN has a process for vetting that is very thorough.

We lower another barrier by subsidizing the initial cost of adoption, requiring tech partners to also provide a discount. If WHIN has done a good job of vetting, the users will benefit and be willing to assume future costs. Once a technology is in wider use, the Alliance serves as a community of users helping each other learn to solve problems in a new way, reducing yet another barrier to adoption. And WHIN remains in the picture to facilitate and advise.

The good news is that lowering these barriers is indeed accelerating the adoption of IoT in the WHIN region. Thirty-nine growers representing nearly 155,000 acres have become Alliance members in the last two years, benefiting from WHIN's weather station network, automated optimization of ag operations, robotic soil sampling, remote grain health monitoring, and aerial imaging. Seventeen manufacturers of all sizes have benefited from automated preventive maintenance technology in a little over a year. Additional technology is in the pipeline for both agriculture and manufacturing members and the Alliances are growing.

WHIN tends to measure the success of its model by the willingness of Alliance members to stay active and begin to invest their own dollars in WHIN's vetted IoT. That won't happen unless farmers and manufacturers are seeing value. The majority of members are being retained in the Alliances from year to year and they are adding new technology.

4.2 Connecting tech companies to real use

One key barrier to innovation is when there is no way to do product validation, which requires real use. And the more expertise that can be brought to bear on resolving problems the validation uncovers, the better the result in both quality and speed.

Purdue University's presence in the WHIN region is of immeasurable value to discovery and innovation. They are leaders in sensor development, and in creating the next generation of digital agriculture and digital manufacturing. They are a tremendous source of expertise.

WHIN's Alliance model brings tech partners into the region who are learning from the real use of their products, whether that is early stage product validation or later stage mature product innovation.

Purdue and the Alliances give tech partners every reason to develop a permanent physical presence in the WHIN region: it is there that they can develop and innovate most quickly and effectively. We have already seen this to be the case. Digital ag company and WHIN tech partner, Solinftec, moved its global headquarters from Brazil to West Lafayette because of the WHIN relationship and proximity to Purdue. All of the other tech partners have also added jobs because of increased business in the Alliance. Some had no previous employment presence in Indiana at all.

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The tech partner relationship also leads to accelerated commercialization of promising near-commercial technologies, helping startups succeed, plant and grow. Two of WHIN's tech partners began as startups in the Alliance and are now further along in their lifecycle.

Thus the Alliance model fulfils another WHIN goal: helping globally-competitive businesses plant and grow in our region, which is to say, to create good jobs.

4.3 Connecting researchers and educators to real use

Funding for university research is highly competitive. WHIN's Living Lab offers Purdue faculty something no other university enjoys: access to a wealth of real world data. The Living Lab actually reverses the conventional science-to-practice model.

A key aspect of WHIN's 501c3 status is that our scientific and educational purposes must also be fulfilled for the public good. WHIN accomplishes these purposes by requiring its Alliance members and tech partners to license data to WHIN. WHIN maintains the data in anonymized form in a data lake, with a data portal that makes it accessible to interested faculty and students.

The intent of WHIN's data sharing is to spur the contribution of university research and innovation toward making the region a global center for IoT. In fact, WHIN data that is generated from sensors can help inform research that is not specifically related to the sensor side of IoT. Because IoT is a complex of data measurement, data transmission, and data analytic technologies, researchers in any one of those areas can benefit from real world data. And because IoT is about the physical world, researchers interested in what the physical world has to say for itself could benefit from real world data. And because IoT is changing and guiding human experience, there is a sociological, ethical, communicative, and even philosophical interest in what is actually, objectively, happening. IoT will increasingly touch most of human experience.

4.4 Connecting products to real use -- the broadband challenge

The digital divide points to a different problem with connecting technology to real use. There is a third variable as the economics of technology innovation and deployment works against adoption.

But building a network doesn't have to be a billion dollar project. It is possible to build small scale networks and connect them to a commercial network with the right technology, incentives, and relationships.

The Living Lab has all of those. As the aerostat story shows, a single piece of gear can make a difference, and WHIN's model is able to incentivize industry partners to come together to help, from fiber to retail operations.

5.0 Urgency

Just how important is WHIN's digitalization project?

According to the pivotal 2019 USDA report, "A Case for Rural Broadband: Insights on Rural Broadband Infrastructure and Next Generation Precision Ag Technologies." (https://www.usda.gov/sites/default/files/documents/case-for-rural-broadband.pdf), the digitalization of agriculture can help growers by:

- Integrated decision-making based on actionable data and information=better decisions, more precise supply chain and resource allocation
- Automation of processes through the Internet of Things=increased efficiency, reduction of repetitive manual tasks, improved precision
- Technology to support human tasks=improved speed, accuracy, ability to access information and control remotely
- Better connectivity=ecommerce, access to more markets, online platforms that are not limited to geography, ability to differentiate products
- Quality of life applications=telehealth, distance learning (including workforce development like developing coding skills)

The report concludes, “While digital technologies are already creating value within the agriculture industry today, realizing the full potential of these technologies, according to USDA, could create $46-$65 billion annually in additional gross benefit for the U.S. economy. In other words, if broadband internet infrastructure, digital technologies at scale, and on-farm capabilities were available at a level that met estimated producer demand, the U.S. could realize economic benefits equivalent to nearly 18 percent of total production, based on 2017 levels. ”

The impact of increased digitalization in manufacturing has also been found to be critically important. “State of renewal: Charting a new course for Indiana's economic growth and inclusion.” (indianagpsproject.com) was released in February, 2021, by the Brookings Institute, in collaboration from the American Enterprise Institute and is the outcome of the Indiana GPS project.

The GPS study was commissioned by the Central Indiana Corporate Partnership (CICP) with funding from Lilly Endowment, Inc., to identify data-driven strategies to promote growth and prosperity in the state. Specifically, those strategies were to be focused on increasing the number of good jobs so that every Hoosier can support a family.

The study picked up on some very important and interrelated data points. A leading indicator of the potential for good job growth is productivity. The most impactful variable for lifting productivity is technology, specifically information technology, which since the mid-90s accounts for 2/3 of productivity growth nationwide. The number one recommendation in the report for creating new good jobs is therefore to accelerate digitalization, including closing broadband gaps as broadband is critical infrastructure both for itself and for digitalization.

This is of utmost importance to Indiana, a state that has suffered from negligible growth in productivity between 2007 and 2019, and whose 2019 productivity gap relative to the nation was 20%. Not surprisingly, given the interrelationship between productivity and digitalization, Indiana's firms are found to be investing too little in IT, ranking the state 37th in the U.S. in annual per worker IT expenditures in 2016, the most recent year for which the data is available.

The report concludes that digitalization leads to economic dynamism, productivity, and competitiveness, with productivity a kind of first among peers as it affects competitiveness and, because of multiplier effects, economic dynamism.

Thus WHIN's model of accelerating digitalization in jobs-rich manufacturing has only become more urgently needed. And WHIN's inclusion of product-rich agriculture in its digitalization project gives ag a new role in impacting jobs as well. The ag tech companies WHIN is working with to digitalize agriculture are creating new, good jobs in Indiana. As part of the advanced services sector, those companies are just as important to Indiana's growth and prosperity as manufacturing.

WHIN now finds itself in the position of being the pilot for the number one recommendation in front of Indiana policy makers and officials for moving the state forward. It is a responsibility we do not take lightly.

6.0 WHIN's value propositions and why it is so important to strengthen and grow its model

One of the great gifts of the LEI grant that created WHIN is that it meant that WHIN is a 501c3. Being a not-for-profit organization enables WHIN to function as an agnostic problem solver, with no allegiance to any particular technology except that it has to be IoT or related to IoT. This enables us to work holistically, with the purpose of problem-solving, whatever it takes, and not simply validating that something works.

That makes us a very new kind of stakeholder in technology innovation that, from a position outside of the innovation value chain, is able to disrupt the chain in the interest of both adoption/digitalization and innovation simultaneously to get problems solved.

WHIN may be outside of the innovation value chain, but its way of disrupting adds great value. WHIN disrupts by separating real use from adoption and then accelerating the use ahead of adoption.

Real use, which is normally delayed until adoption, is the only way to answer the questions that measure real value: does the technology work as intended? Is it something the market needs? Does it solve a problem users care about? How much value will it return and how quickly? Are there any unintended consequences? And most of all, will someone pay to use it?

This last point is key. WHIN describes itself as accelerating adoption and it is. But it doesn't do that with its initial investment in reducing the cost of adoption. Adoption doesn't really happen until the user is paying for the technology, until they have literally bought in. In the first years a technology is deployed in the region, WHIN assumes the risk that adoption may not ultimately occur. Indeed, for technology laggards like farmers and manufacturers, for whom seeing is often the shortest route to believing, what WHIN offers is basically an extended road test.

WHIN's ability to take on the risk is enabled by its own investors.

And the risk is worth it. Real use is what uncovers problems, and WHIN's model of doing that earlier can mean the difference between an inexpensive adjustment and complete failure of the product. The earlier a problem is found, the less likely it is to damage the trajectory of product development. Indeed, even failure can be innovation's best friend, as long as it occurs early. Failure is the source of much critical learning. This is called "fail fast" in technology development and it helps ensure that companies adapt quickly and move on without spending more time on something that isn't working.

Another trend in tech development is to send products to the market early, when they are ready to do a meaningful task but could still benefit from additional features. The products can often be easily updated through software updates and, in the meantime, the user has the benefit of the features that are available, and the tech company can ensure the product is keeping pace with user needs. This solves the problem of long development cycles aimed at perfection which can mean that, by the time the product is perfect, user needs have changed and the product is obsolete before it gets out of the lab. The principle is to not let the perfect get in the way of the good.

More generally, these trends reflect how the private sector is adapting to the rapid pace of technological change during the development phase, which also requires substantial investment. In effect, the companies are protecting their investment in development by accelerating real use.

Indeed, the strategies can be seen as a form of "future proofing." The concept of useful life that is the usual target of "future proofing," is based on a rigid innovation value chain model that positions the user at the end of product development, after all of the value has been built in. When users need change, which is the main source of obsolescence, the product loses use value.

But if real use is distributed all along a product's value chain, the product can better keep pace with need and, as a bonus, uncaught problems are less likely to interfere with future development and value. Distributing the risk all along the value chain makes it more likely that, barring a revolutionary shift in technology, the product will last longer.

That is what is proven in the private sector to handle accelerated change for single technologies.

WHIN's Living Lab model takes those strategies further. First, it creates a community of users in a very large lab with diverse conditions that enables a much more robust test for even single products.

And, because it is operated by WHIN, which is agnostic to any particular technology, the model is able to accommodate complex technologies like broadband, which depend on entire systems of products to solve a problem. WHIN is able to help design and test complex solutions, in the quest for what is cost-effective and sustainable, beyond simply knowing whether an individual component performs according to spec.

For investors all along the innovation value chain from the NSF to VCs to the USDA investing in broadband deployment to users themselves, early certainty--in whatever degree-- reduces risk,, and makes it possible to release investment earlier throughout the innovation value chain. This keeps innovation and digitalization moving forward.

Finally, and most important, it should not be lost that WHIN's Living Lab, by being Living, necessarily includes the community itself in finding the right solutions. Grounding the innovation of technology in real use also keeps it grounded.

The Living Lab is the right model for the right time: a way to manage both complexity and rapid acceleration of change in broadband and all of the aspects of digitalization, and a way to connect technology to what is humane and real.

Johnny Park

1281 Win Hentschel Blvd.
West Lafayette, IN 47906
johnny@WHIN.org

Johnny is CEO of Wabash Heartland Innovation Network (WHIN), a consortium of 10 counties in north-central Indiana devoted to developing the region into a global epicenter of digital agriculture and next-generation manufacturing by harnessing the power of IoT (Internet of Things). Prior to WHIN, Johnny founded, scaled and led a successful exit of an agtech company, Spensa Technologies, focused on smart IoT devices and data analytics to help growers better manage agronomic pests such as insects, weeds and disease. Spensa was named by Forbes as one of the Top 25 Most Innovative Ag-Tech Startups in 2017. Before Spensa, Johnny was a faculty in the School of Electrical and Computer Engineering at Purdue University where he served as Principal and Co-Principal Investigator of $12M research projects in robotics, computer vision, machine learning and distributed sensor networks. He supervised and co-supervised 10 PhD students, published over 50 peer-reviewed papers and was granted 4 patents. Johnny received his BS, MS and Ph.D. degrees all from the School of Electrical and Computer Engineering at Purdue University.

Professional Experience

2018 - present	CEO, Wabash Heartland Innovation Network (WHIN)
2019 - present	Agriculture Advisory Council for US Senator Mike Braun
2018 - present	Board Director, AgriNovus Indiana
2009 - 2018	Founder and CEO, Spensa Technologies (acquired by DTN)
2008 - 2014	Research Assistant Professor, Electrical and Computer Engineering at Purdue University
2004 - 2008	Principal Research Scientist, Electrical and Computer Engineering at Purdue University

Education

Purdue University	Electrical and Computer Engineering	PhD, 2004
Purdue University	Electrical and Computer Engineering	MS, 2000
Purdue University	Electrical and Computer Engineering Minor in Economics	BS, 1998